Return to the Moon: The Great Basin Lunar Sample Return Mission

Craig Peterson

4th IAA Conference
Low Cost Planetary Missions
May 3, 2000

JPL

Outline

- Study Team
- Science Objectives
- Mission Design
- Spacecraft Design
- Q & A

JPL NASA

Lunar Sample Return Study Team

- Charles Budney, Robert Gershman, and Craig Peterson

Subsystem	Advanced Products Development Team Members
Study Leader	Bob Oberto
Science	Dave Senske, Charles Budney
Mission Design	Julie Kangas
Ground Systems	Mark Rokey, Rob Lock, Terri Anderson
Systems	George Sprague
Instruments	Jim Anderson, Charles Budney
Propulsion	Mike Leeds
ACS	Ed Mettler, Ed Swenka
CDS	Vince Randolph, Wai-Chi Fang
Power	Sal DiStefano, Leela Hill
Thermal	Bob Miyake, Partha Shakkottai
Structures	Gerhard Klose, Kobie Boykins
Telecom-System	Anil Kantak
Telecom-Hardware	Faiza Lansing, Ali Ghaneh, Mary Boghosian
Cost	Kevin Roust,
Documentation	Larry Palkovic

Science - Why Go Back?

- To collect samples of lunar mantle material from the floor of the Apollo Crater in the South Pole–Aitken Basin on the lunar farside (landing site: 38.22 S, 206.7 W) and return them to Earth.
  - These samples will provide information on mantle composition and age, planetary accretion near the Earth, formation of the Earth-Moon system, and dynamics of very large impacts.
- Compositional information will provide a means to test models of lunar formation, including the hypothesis that the Moon formed as a result of an impact between the proto-Earth and a "Mars sized" impactor.

JPL

NASA

Science - Why Go Back? (continued)

- Detailed geochemical information and age dating will constrain the initial differentiation of the lunar magma ocean and possible overturn of the cumulates that formed in that ocean.
- Distributions of different rock types will help constrain the motion of materials during the impact process that formed lunar basins.
- Information may also be available on the composition of impactors that formed lunar basins.
- At 2500 km in diameter and over 12 km deep, it's the largest known impact basin on the Moon (or the Solar System).
  - Impact cratering models suggest that this basin should have excavated material from the lunar mantle

JPL

NASA

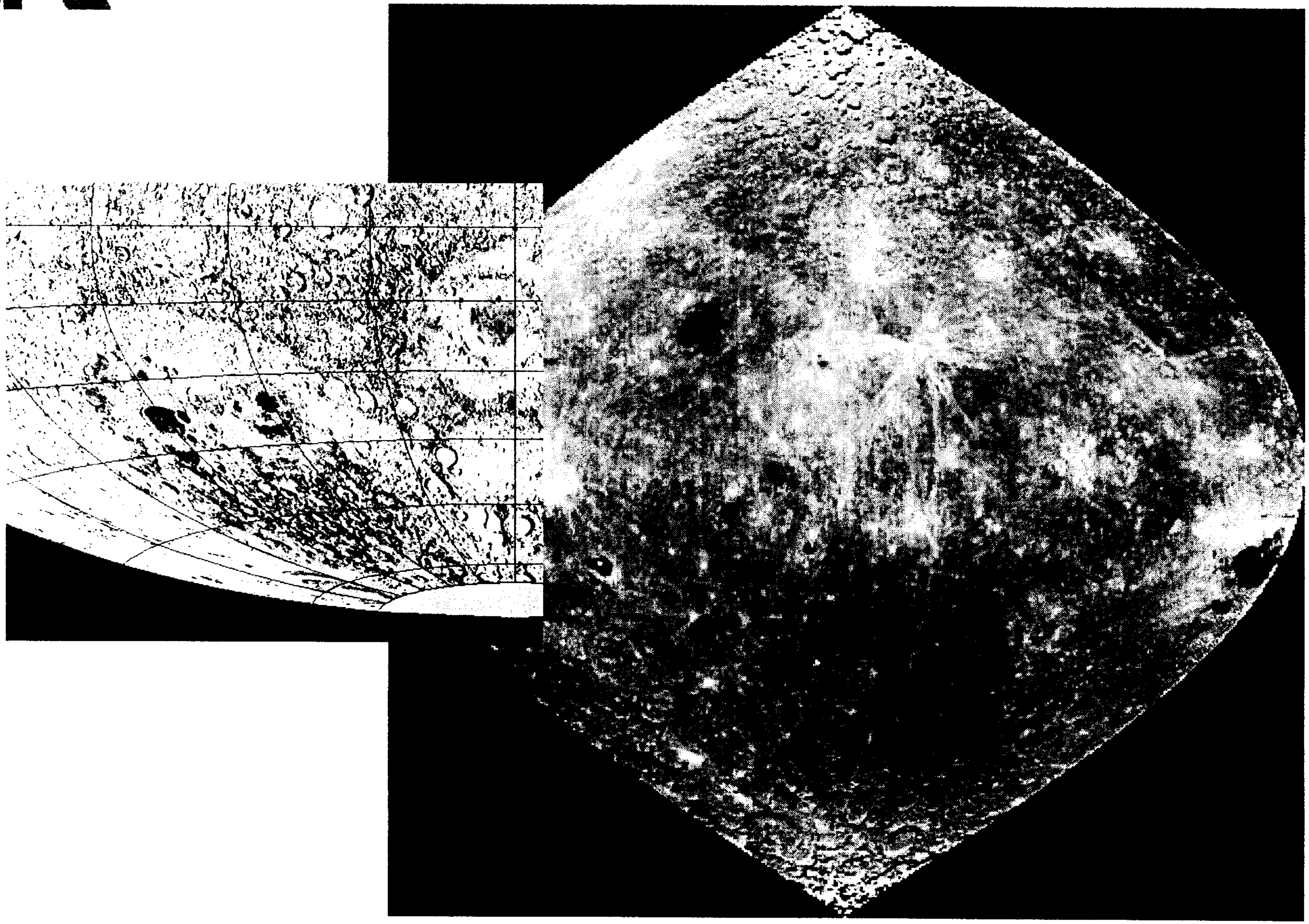


Figure 3: Sinusoidal Projection of the Lunar Farside
The dark, circular area near the bottom center of the image is the interior of the South Pole–Aitken Basin

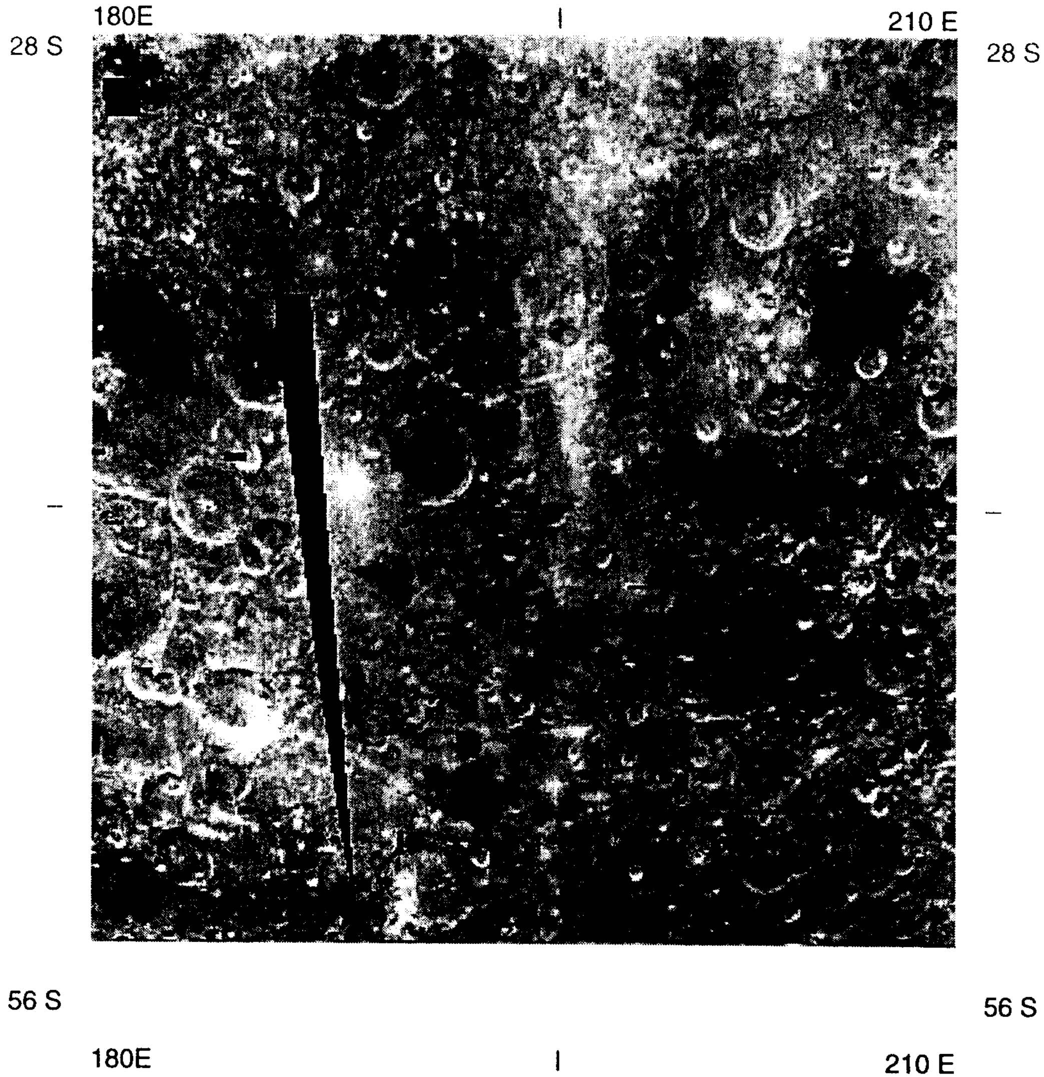


Figure 2: Regional Image of the Lunar Farside

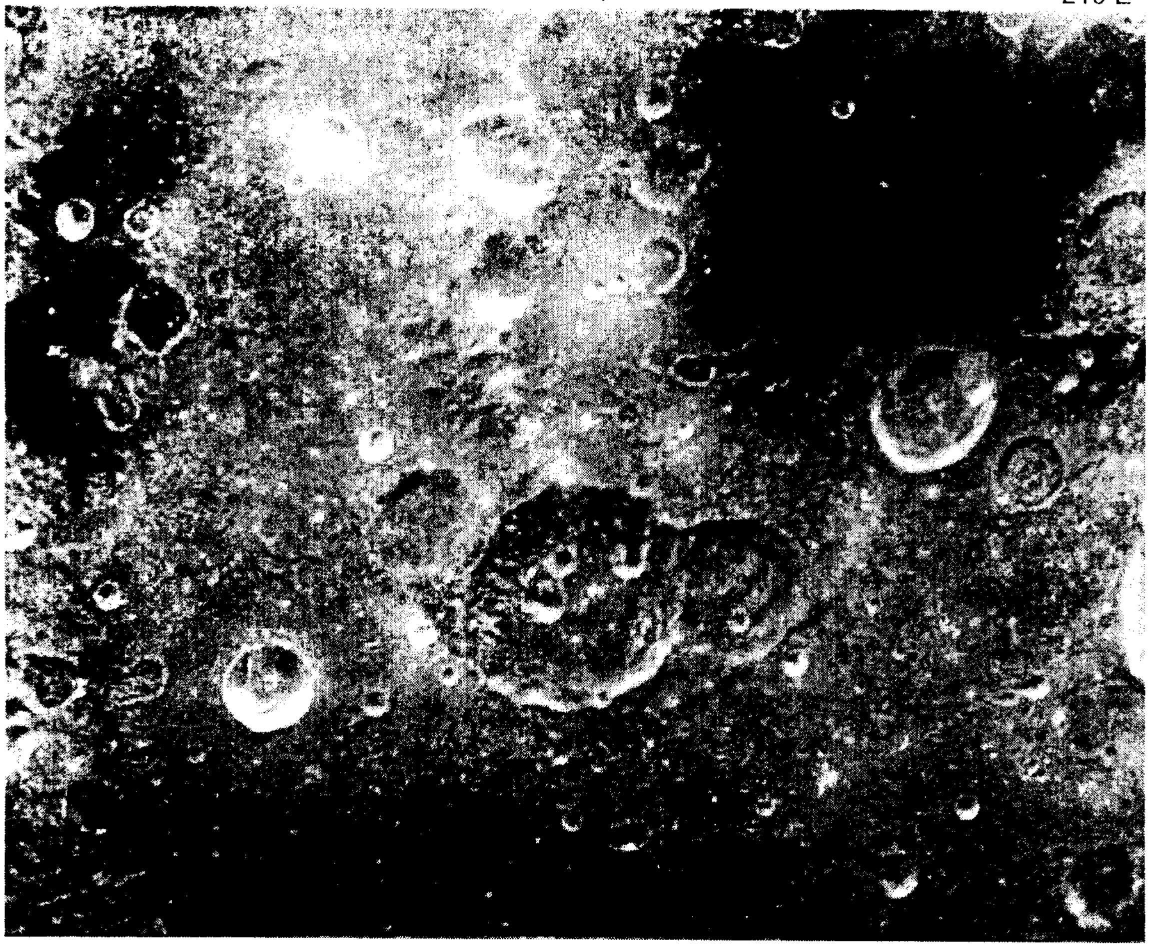


Figure 1: Landing Site at 38.2 S 206.7 E in the South Pole–Aitken Basin

Image scale ~260 km × 210 km

Lunar Sample

- Material to be acquired for the Lunar Basin Sample Return Mission totals 4.6 kg
  - mass is based on sampling discussed in Geoscience and a Lunar Base NASA CP-3070, 1990
  - amount of material to return from this mission is larger than in the 1990 report due to desire to locate and return lunar mantle material from the South Pole–Aitken Basin
  - rover can cover a large area and collect a wide variety of samples rather than the simple grab and run mission discussed in the Geoscience and Lunar Base report.
- The lunar sample consists of:
  - One regolith core 2 m deep by 1.5 cm in diameter with a mass of 1 kg.
  - Selected rocks in the 1- to 4-cm size range totaling 3 kg.
  - Bulk regolith samples totaling 0.6 kg.

Sample Selection

- Best way to identify potential mantle rocks is analyzing chemistry and mineralogy of each sample
  - Models of mantle formation and remote sensing of the interior of the South Pole–Aitken Basin suggest that mantle material should contain 10 to 16 % by weight FeO and <0.1 % by weight TiO2
  - Mantle mineralogy is expected to consist of cumulates of olivine, pyroxene, ilmenite; possible urKREEP; and possibly peridotites or dunites. This mineralogy should be different from lunar crustal rocks and mare basalt. Olivine is a key mineral for distinguishing mantle samples. Identification of thorium would also be useful
- Science Implementation on the Rover
  - Chemistry, by X-ray fluorescence (XRF) spectrometry
  - Mineralogy, by visible/NIR spectrometry

Sample Context

- Main objective of sample context is determination of the exact location of the landing site
  - High-resolution images of the landing site will also be useful for planning rover traverses
  - Images showing the locations where the samples are collected are desired but not required
  - Context information for samples sifted from the lunar regolith, which are scattered from impacts, are not as important as they are for samples collected in other geologic contexts
- Science Implementation
  - Monochrome imaging on the descent stage and the rover
  - Multispectral imaging on the lander

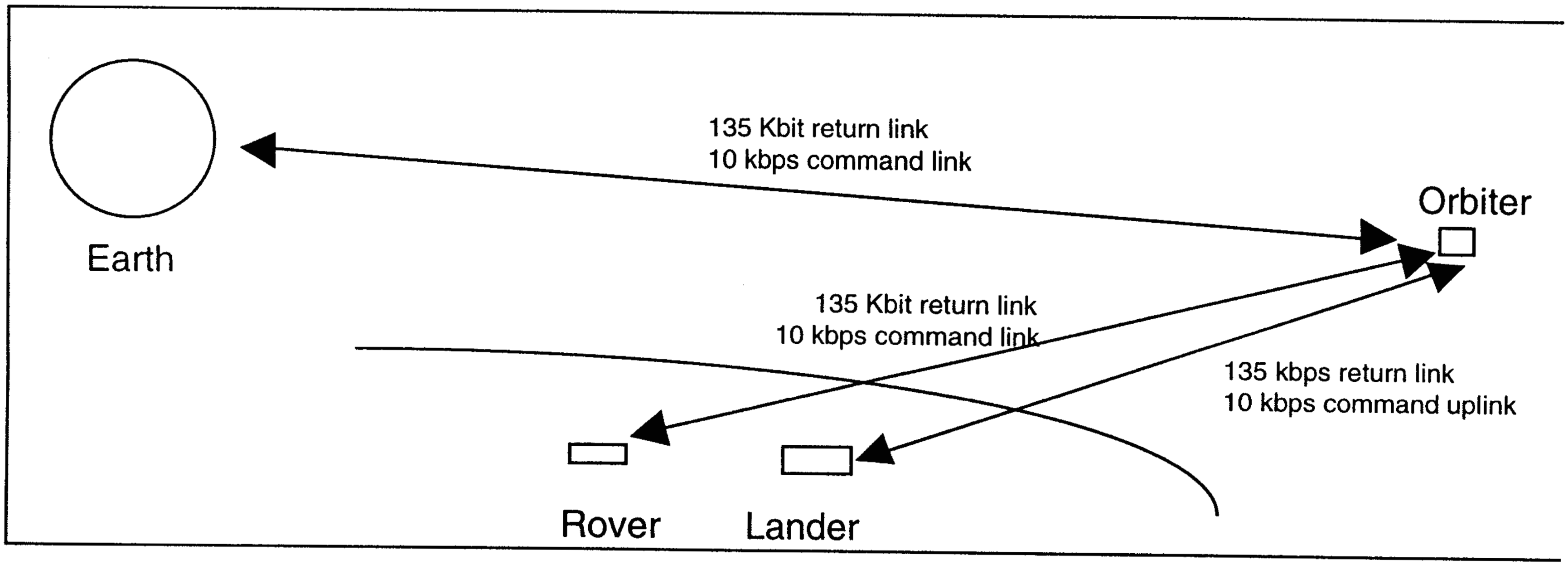
Science Operations

- Collect descent imaging as lander approaches surface
  - begin at 200-m resolution and continue in factor-of-2 steps down to surface yielding 10 to 12 images of 1024 × 1024 pixels at 10- to 12-bit image depth
- Panorama of the landing site (ala' Sagan Memorial Station)
- Lander obtains bulk regolith sample and bulk rock rake sample about 0.5 kg each
- Lander obtains a regolith core sample
- Rover loops out from and back to the lander, each more ambitious than the last, also collects image data
  - rover rakes soil to collect 1- to 4-cm rocks, performs chemical and mineralogical analysis to determine candidates for return
  - candidates are placed in a documented sample bag and stored in a temporary sample cache on the rover, then in the sample can on the lander.

Mission Design

- Novel sample return scenario compared to other studies
- Instead of a direct Earth return or rendezvous in lunar orbit, both very costly in energy terms, this study employs a rendezvous in Earth orbit
  - The LAV launches in a western direction (lunar retrograde) from the lunar surface and enters a high-altitude Earth orbit
    - eastern launches, while providing a small ΔV advantage, tend to rapidly leave Earth orbit
  - The relay orbiter on station at lunar L2 to provide a telecom link to the lander
    - rendezvous with the LAV anywhere from 2 weeks to possibly a month after lunar escape

Telecom Strategy



Orbital Mechanics

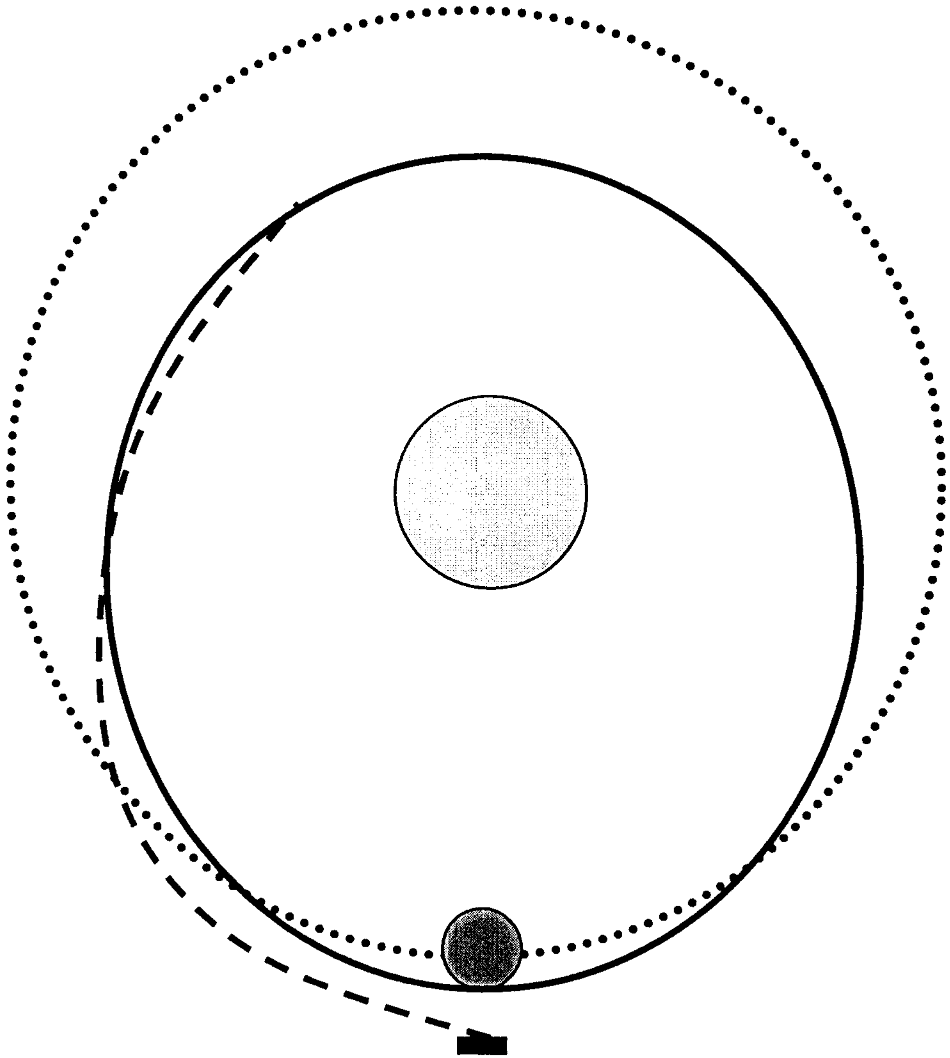
Table 3: ΔV Breakdown for Lunar Lander in m/s

Arrival/Landing	2500
Gravity Losses	175
Approach TCMs	100
Arrival Variation Allowances	125
Total	2900

Table 4: ΔV Breakdown for Relay Orbiter in m/s

L_2 divert, insertion, and stationkeeping	400
Transfer from L_2 to sample trajectory	450
Terminal Rendezvous	100
Earth Return	500
Contingency	350
Total	1800

Rendezvous (not to scale)



JPL

NASA

Lunar Canister Tracking Strategy

- Three options available for tracking sample canister:
  - One-way Doppler in S-band from DSN 34-m
    - Requires oscillator stability on the order of 1 part per billion (not as precise as USO, more precise than AuxOS).
  - Two-way Doppler in S-band from DSN 34-m BWG
    - Requires transponder-like receiver and clock
  - Radar from Arecibo or Goldstone
    - Radar was used for the SOHO recovery, with Arecibo transmitting and Goldstone receiving, to obtain very high-fidelity data such as attitude and spin rate
  - Proximity sensors needed for terminal rendezvous
    - Options include radio direction-finding relying on a low-power, one-way beacon on the sample; laser range finder; and optical (stereo helps). When orbiter within 0.5 to 2 km, feedback and accuracy of proximity sensors becomes the dominant information source.
- Note on terminal rendezvous autonomy: Quasi-autonomous terminal rendezvous technology has been in use since Apollo

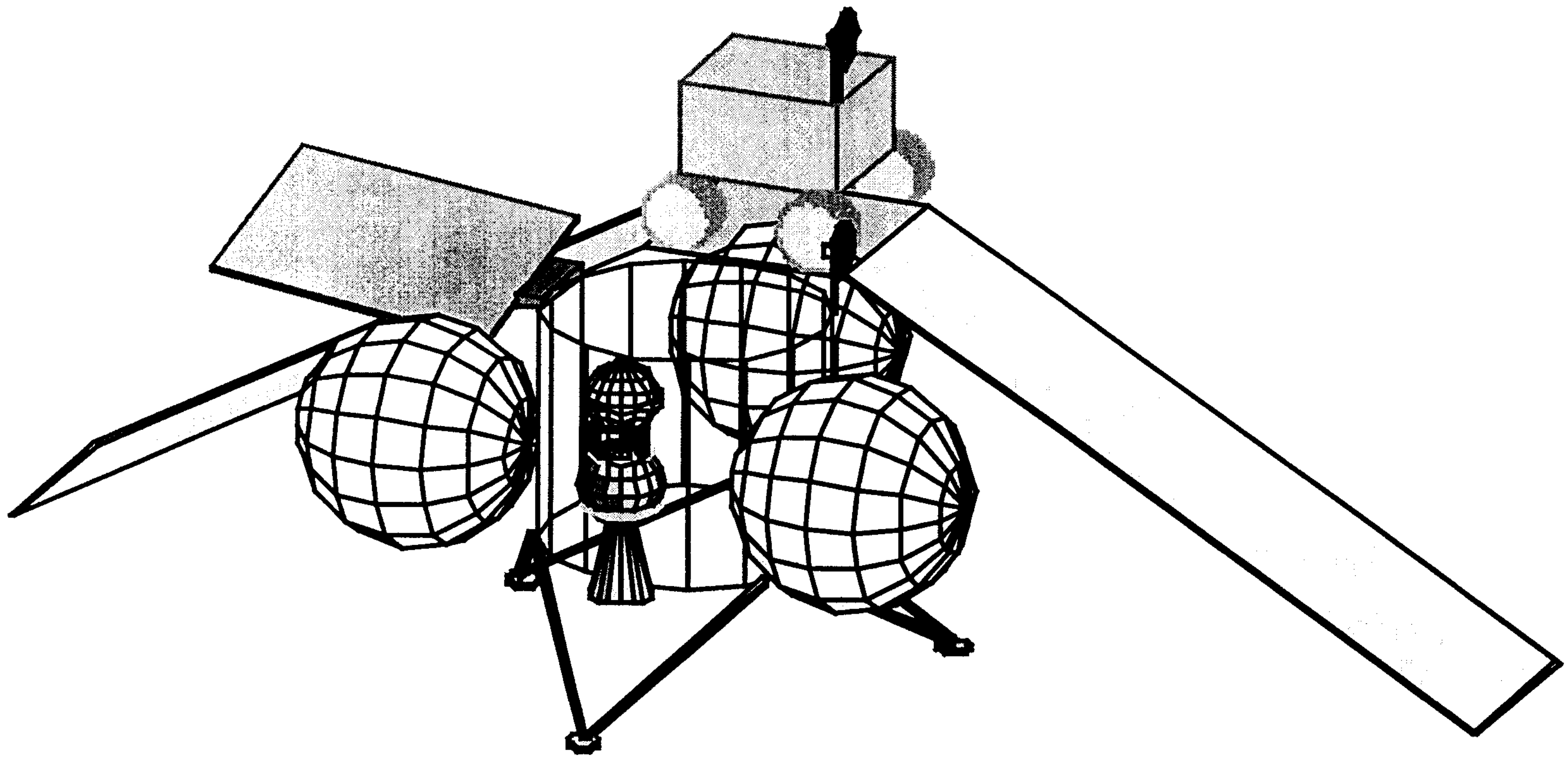
Flight System Summary

- Four distinct elements: the Lunar Ascent Vehicle (LAV), the Lunar Lander, the Lunar Rover and the Relay Orbiter
- All designed to be launched simultaneously on a single Atlas IIIA
- Lunar Rover volume and mass based on currently planned rovers
  - New Instumentation was specified for the rover
- Orbiter functions as both comm relay to Earth while rover and lander collect samples and as rendezvous vehicle for returning the samples to earth

Flight System Summary (continued)

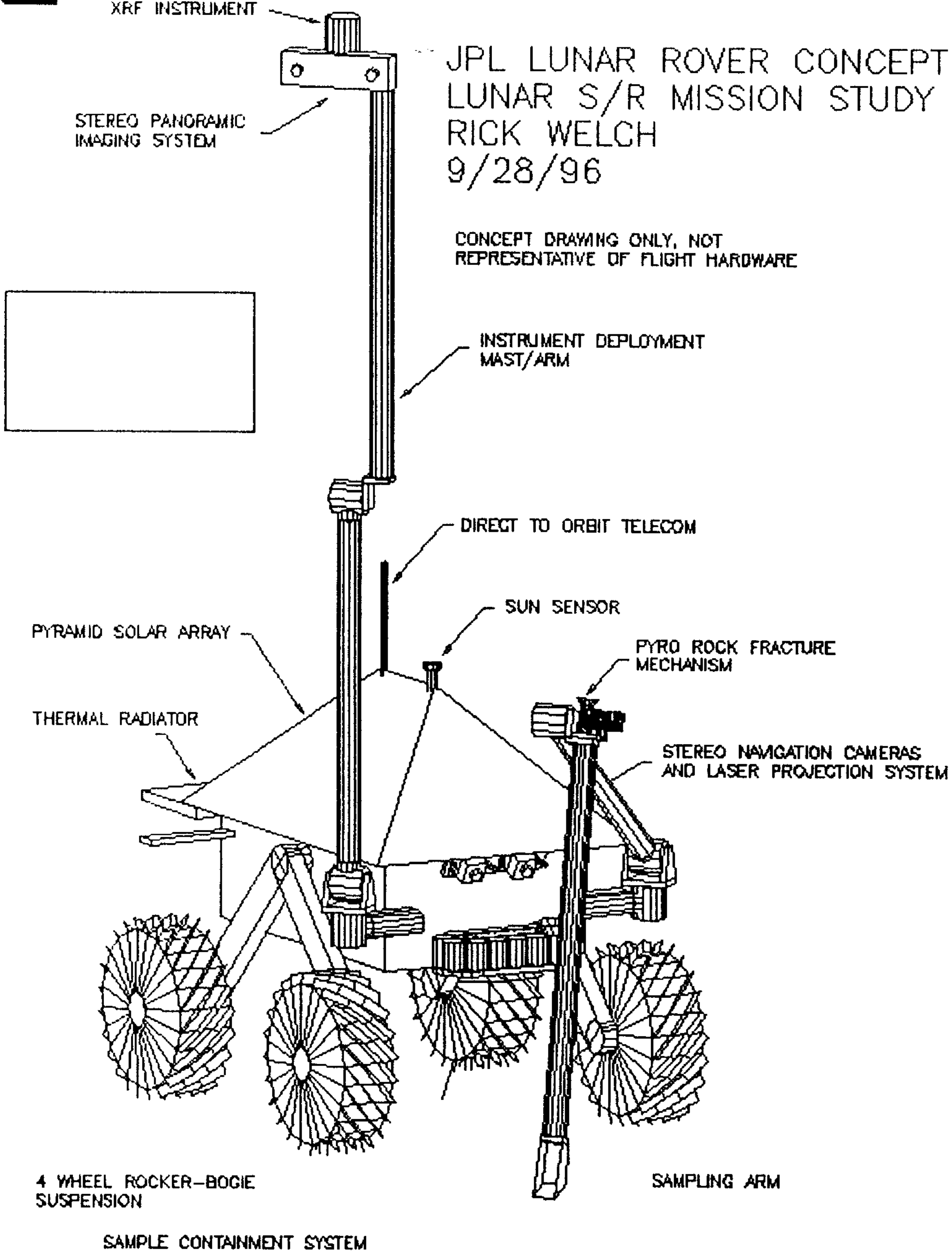
- The lunar lander functions as launch platform for the LAV and for drilling for lunar samples
- The LAV has been simplified as much as possible to return the samples to the relay orbiter.
  - The LAV propulsion system uses a single-stage, solid rocket motor (SRM) to boost the 4-kg lunar sample into orbit. The SRM is a derivative of the Thiokol Star 13A.
- The propulsion systems for both the lander and relay orbiter are similar dual-mode systems
  - lander requires the development of a new-design, throttleable, main engine valve.
- Subsystems designed to minimize mass and use technology readily available for a 2008 launch date.

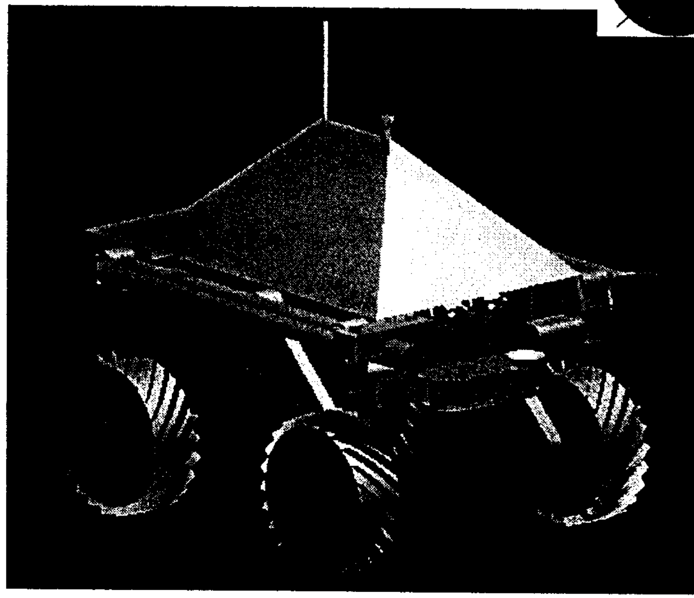
Lander, Lunar Ascent Vehicle, and Rover deployed on surface

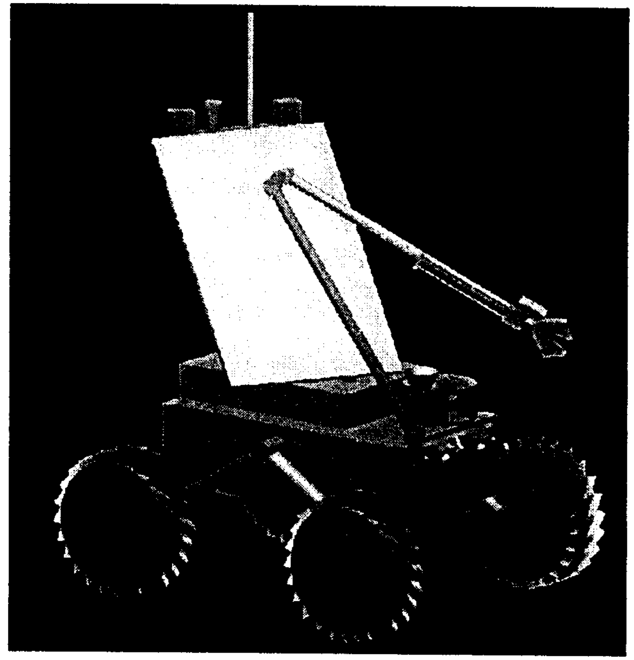


JPL LUNAR ROVER CONCEPT
LUNAR S/R MISSION STUDY
RICK WELCH
9/28/96

CONCEPT DRAWING ONLY, NOT REPRESENTATIVE OF FLIGHT HARDWARE



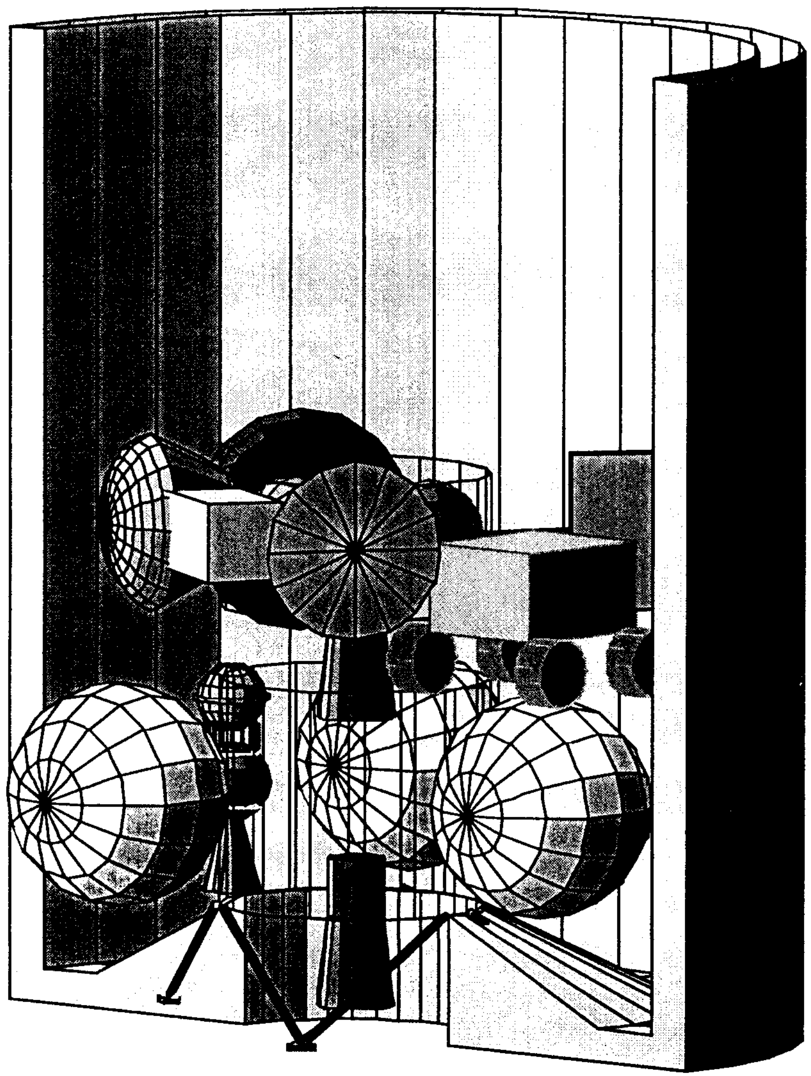




JPL

NASA

Spacecraft in Launch Vehicle Fairing



Mass and Power Summary (1)

	Mass (kg)	Power (W)
Sample Ascent Vehicle	**56.4**	**1.5**
Payload total	9.7	
Canister	4.4	
Beacon, Solar Cells	0.70	
Sample	4.6	
Lift System total	9.7	1.1
Command and Data	0.21	1.0
Power	0,52	0.1
Propulsion (Star 13A)	4.54	
Structure	2.69	
LAV Adapter	1.53	
Cabling	0.19	
Mass/Power contingency	4.4	0.3
Propellant	32.6	

Lunar L2 Orbiter (wet)	**591.0**	**209.6 (TCM)**
Payload total	90.0	
Sample Capture	50.0	
Earth Entry Vehicle	40.0	
Orbiter Bus total	159.5	161.2 (TCM)
Attitude Control	5.4	21.8
Command & Data	1.3	7.4
Power	6.0	17.3
Propulsion (dual mode)	31.4	
Structure	82.5	
S/C Adapter	7.8	
Cabling	8.9	
Thermal	9.4	16.5
Telecom (high gain X-band	6.8	29.5
Mass/Power Contingency	74.9	48.4
Propellant and Pressurant	266.7	

Mass and Power Summary(2)

	Mass(kg)	Power(w)
Lander (wet)	**1913.0**	**666.9 (Core Drilling)**
Payload total	167.4	430.0
Instruments	26.1	430.0
Rover	68.0	
Ascent Vehicle	56.4	
Ascent support eqpt.	16.9	
Lander Bus total	386.7	122.1 (descent/landing)
Attitude Control	13.9	44.0
Command & Data	1.3	7.4
Power (2.2 m^2)	7.1	14.3
Propulsion (dual mode)	51.9	
Structure	261.3	
S/C Adapter	8.8	
Cabling	24.1	
Thermal	14.1	34.3
Telecom	4.2	22.1
Mass/Power Contingency	128.9	153.9
Propellant and Pressurant	1230.0	